INTRODUCTION

In the early 50s, there was no restorative material available that had appreciable adhesion to tooth structure under oral conditions. The main aim was to develop restorative materials capable of forming strong bonds to tooth structure. These in turn would offer many advantages. Resistance and retention forms in cavity preparations would be less critical. Such a material could be used in sealing pits and fissures for caries prevention and in the repairs of incisal fractures without the need for cutting tooth structure. The leak-proof cementation of crowns and bridges would be possible. These and many additional advantages led to the development of adhesive restorative materials.

Caries rate has been continuously dropping and people have been able to retain their teeth for longer periods of time. Hence, the need for more complex restorations beyond the limitations of amalgam and direct composites has become widespread. The result being an increased demand for indirect restorations like inlays, onlays, crowns and bridges. With the availability of adhesive materials the expectation of society has changed towards more permanent restorations.

Each year, manufacturers introduce new bonding systems and new resin cements to improve the clinical performance of various restorative materials. Adhesive dentistry has expanded to accommodate indirect resin composite inlays and onlays, adhesive cast metal restorations, bridges and ceramic restorations. A lot of
materials have claimed the ability to bond to tooth structure, thus, making it necessary to study their performance. Since clinical studies are lacking, much attention has been placed on in vitro studies of bond strengths.

In a cast restoration system, luting agents are considered to be a weak link. For a restoration to be successful, it is important to improve this link i.e. improve the bond strength between the restoration and the tooth structure. The retaining capability of a luting cement has been evaluated using shear bond strength measurement for a long time in dentistry. In a shear test the bond was broken by a force working parallel to the tooth surface. Therefore, the aim of this study was to compare the shear bond strength of metal castings luted to dentine using three different resin cements.

METHODOLOGY

Thirty six sound extracted premolar teeth were used in this study. The teeth were divided into three groups of twelve teeth each.

Calculus and soft tissue deposits were removed from the selected teeth using ultrasonic scaler. The teeth were then stored in 0.5% chloramine at room temperature. The solution was changed periodically after every fifteen days.

The teeth were mounted using clear cold curing epoxy resin (Mirapox 950-230 A) in plastic holders (Buehler® Sampl-Kup®). The teeth were mounted in such a way that the occlusal surfaces were flushed with the top surface of the mounting resin as shown in Figure 1. The mounted specimens were then stored in tap water until used.

The metal used was a chrome cobalt alloy for model casting, Metaplus® VP Hard 1000-50 (AZ & Partner AG, CH-Reiden).

A sharp metal strip was welded at both ends to form a circular ring of 3.8 mm diameter. This circular metal ring was used to punch out the wax pattern (modeling wax) for the fabrication of the metal discs. The pattern was invested with Complete® Investment (Jeneko®, USA) and the discs were prepared using Induction Casting method with Induction Casting Machine (Bego, Fornax 35EM).

The castings were ground flat on one surface on a water-cooled abrasive wheel (Struers, Rotopol-1). The flat metal surfaces were sandblasted with 50μm aluminium oxide particles using Topstar® (Bego, W Germany). The discs were then steam cleaned using Triton® (Bego, Germany).

The occlusal enamel was removed to expose a flat dentine surface perpendicular to the long axis of the tooth initially on a 180 grit-silicone carbide paper. When dentine exposed, it was finally polished on a 500 grit-silicone carbide paper under water coolant (Struers, Rotopol-1). In order to minimize deviations resulting from differing dentinal depths, all tooth surfaces were ground only to a depth sufficient to create a flat surface area of dentine adequate to accommodate the 3.8 mm diameter metal discs.

The metal castings were cemented with Panavia F, Variolink II and Super-Bond C & B to the first, second and third groups of teeth respectively following the manufacturer’s instructions as shown in Table 1.

During cementation, a constant force of 10 Newton was applied for ten minutes to each sample as shown in the assembly in Figure 2. This was done to ensure
a controlled film thickness of the luting cements to all the specimens.

The specimens were then stored at 37°C in 100% relative humidity for 24 hours prior to testing.

Shear bond strength testing was carried out on the Instron Universal Testing Machine (Instron 4302, Instron Corporation) at a cross-head speed of 1 mm per minute.

The prepared test specimens were held in place using a shear jig. A chisel shaped shearing blade (0.5 mm blunt edge), attached to the cross-head, was aligned parallel to the flat dentine surface of the bonded specimen. The assembly is shown in Figure 3.

The shear bond strengths (MPa) of the metal discs was calculated from the cross-sectional area (πr²) of the cemented discs using the following formula:

Shear bond strength (MPa) = Force (Newtons) / Area (mm²).

The peak load i.e. the force to debond the bonded metal disc-dentine assembly was recorded from the Instron Universal Testing Machine for each specimen. The area (11.35 sq mm) was constant for all the specimens.

RESULTS

Panavia F (Group I), Variolink II (Group II) and Superbond C & B (Group III) were compared to see the difference in their adhesive strengths.

Groups I, II and III (mean shear bond strengths were 25.93 ± 4.95 MPa, 3.90 ± 1.76 MPa and 17.84 ± 5.00 MPa respectively) were analysed using “Anova: Single Factor”. The mean shear bond strengths between the test groups showed that there was a statistically significant difference between the groups at p < 0.05. Post-hoc Scheffe’s Analysis was then performed at p < 0.05. This gave the Scheffe’s Confidence Interval, “I” which was equal to 4.40 as shown in Table 2. From this value

TABLE 1: LUTING PROCEDURES FOR THE RESIN LUTING CEMENTS

<table>
<thead>
<tr>
<th>Material</th>
<th>Conditioning</th>
<th>Priming</th>
<th>Bonding</th>
<th>Cementation</th>
<th>Polymerisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panavia F</td>
<td>None</td>
<td>Ed Primer</td>
<td>None</td>
<td>2-paste Light curing 20 seconds</td>
<td>Dual curing resin based cement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60 seconds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gentle air dry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variolink II</td>
<td>Total Etch 15</td>
<td>None</td>
<td>None</td>
<td>2-paste Light curing 40 seconds</td>
<td>Dual curing resin based cement</td>
</tr>
<tr>
<td></td>
<td>seconds wash and dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Super-Bond C &amp; B</td>
<td>Green Activator</td>
<td>None</td>
<td>None</td>
<td>Mixing of Polymer in Monomer and</td>
<td>Self curing dental adhesive system</td>
</tr>
<tr>
<td></td>
<td>10 seconds</td>
<td></td>
<td></td>
<td>Catalyst S 7-8 minutes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wash and dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig 3: Arrangement for shear bond strength testing on Instron Universal Testing Machine

TABLE 2: COMPARISON OF THREE RESIN LUTING CEMENTS USING ANOVA

<table>
<thead>
<tr>
<th>Resin Cement</th>
<th>Mean shear bond strength (MPa)</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panavia F</td>
<td>25.93</td>
<td>4.95</td>
</tr>
<tr>
<td>Superbond C &amp; B</td>
<td>17.84</td>
<td>5.00</td>
</tr>
<tr>
<td>Variolink II</td>
<td>3.90</td>
<td>1.76</td>
</tr>
</tbody>
</table>

Scheffe’s Confidence Interval, “I” = 4.40

Post-hoc Scheffe’s analysis showing no tie line imparting there is a significant difference between all three materials at 95% confidence level.
it was found that there was a significant difference in the shear bond strengths of all the test groups. In other words, shear bond strength of Panavia F was significantly higher than both Superbond C & B and Variolink II, whereas the shear bond strength of Superbond C & B was significantly higher than Variolink II as shown in Figure 4.

**DISCUSSION**

Atta et al.\(^8\) reported that the mean shear bond strengths for Panavia Ex and SuperBond C & B to Ni-Cr alloy was 40.5 and 25.22 MPa respectively. They found that Panavia Ex was a stronger adhesive for these types of restorations. SuperBond C & B had an acceptable range to be successful in certain clinical situations. The results of the present study also showed that Panavia F had the strongest bond with the Co-Cr alloy luted to dentine. Similarly, SuperBond C & B had an acceptable strength.

The bond strength of Variolink II was found to be the lowest (Osman et al.\(^9\) also found Variolink to give the lowest bond strength in their study). It was in the range which could not be acceptable in clinical practice for the luting of adhesive metal restorations without any retentive mode. The reason could be that Panavia F contained a self etching primer and a bonding agent that improved the wetting of the material; whereas Variolink II did not possess such property. The penetration in this case could be less. Monomers used in dentistry are generally liquids and during the process of polymerisation they become converted to solids. SuperBond C & B also contained 4 META which could increase its penetration into the dentine to form the hybrid layer. Moreover, the viscosity of SuperBond C & B was more favourable for penetration of the resin monomers compared to Variolink II. Panavia F paste, having the primer and the bond, did not require penetration and formed chemical bond with the polymerised resin.

Panavia Ex was found to have mean shear bond strength of 27.5 MPa in one study\(^10\) with nickel chromium alloys whereas in another it was calculated to be 15.4 MPa.\(^11\) Different studies showed a lot of variation with the same materials. The reason could be the enormous number of variables involved including substrate variables, storage variables and testing variables.\(^12\)

Cooley et al.\(^13\) reported that the mean shear bond strength of a resin cement containing 4-META (SuperBond) to dentin and metal alloy was 20.1 MPa which was comparable to this study.

Miyazaki et al.\(^14\) suggested that the higher filler levels might decrease the wetting of the dentine surface because of the higher viscosity of filled resins and
as a result the penetration of monomers may be decreased, thus, reducing the shear bond strength. But the presence of the self etching primer increased the penetration of the resin in the case of Panavia F. Moreover, the use ED primer increased the degree of conversion from 50% to 74% which further improved the mechanical properties of the cement. The high viscosity of Variolink II without the use of primer or bonding agent might have contributed to the unpredictable wetting of dentine surfaces and consequently lower strength.

In this study, the storage time prior to testing was 24 hours. It was stated by Geurtsen that the degree of monomer-polymer conversion of most resin composites varied between 35 % and 77%. It was reported that the bond strength of composite adhesive was initially high which doubled within 24 hours and increased minimally thereafter. There was no significant difference found for the time periods of 24 hours and 3 months with Panavia F for the shear bond strengths between Ni Cr Alloy and dentine. It might be possible that Variolink II had not cured sufficiently at the time of testing while Panavia F had reached sufficient amount of conversion.

Polymerisation shrinkage might be another factor associated with differing bond strengths observed in this study. Polymerisation shrinkage may induce localised flaws and stress concentrations that may result in bond failures. The polymerisation contraction of the three luting cements used in this study might be different. Thus, making an impact on the final shear bond strengths of each luting cement.

Some methacrylates containing carboxylic acid (4-META) and phosphate acid ester (MDP) promote chemical bonding to certain metal oxides or passive films such as chromium oxide. These are the essential components of the Superbond C & B and Panavia F respectively. Thus, the formation of a chemical bond might be another factor for the better performance of these two cements compared to Variolink II.

SuperBond C & B cement contains no filler and is largely composed of poorly cross-linked polymethyl methacrylate, it may be more prone to water sorption than Panavia F cement, which is highly filled and cross-linked with strong Bis-GMA. Urethane based materials (Variolink) are also susceptible to more water sorption. Water sorption adversely affect the mechanical properties of the resin. This might be another reason for the high bond strength of Panavia F.

Resin luting cements could form hybrid layers, as well as resin tags in the opened dentinal tubules in a fashion similar to that of direct restorative bonding systems. It was believed that the resin which entered the tubules to form the tags may have some impact on the strength of the bond. The presence of primed dentine, including formation of 4-6 μm resin impregnated intertubular dentine surface and resin tags, could also provide an extremely effective seal and a strong bond. Panavia F might have formed better hybrid layer or resin tags than SuperBond C & B which in turn demonstrated higher shear bond strength. Similarly Superbond C & B might have performed better than Variolink II.

Care should be taken in interpreting these results as a particular adhesive system may have tested well under a set of conditions that do not replicate the clinical conditions of usage by the individual dentist.

CONCLUSION

This study shows that Panavia F could be used confidently in luting routine indirect metal restorations to dentine. As far as Variolink II is concerned, the bond strength for Co-Cr restorations to dentine is inadequate. However, it could be used with caution where retention is not a concern. Superbond C & B showed acceptable bond strength with non-precious metal restorations. This material could be used for high occlusal stress areas as well as non-retentive restorations.

REFERENCES

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